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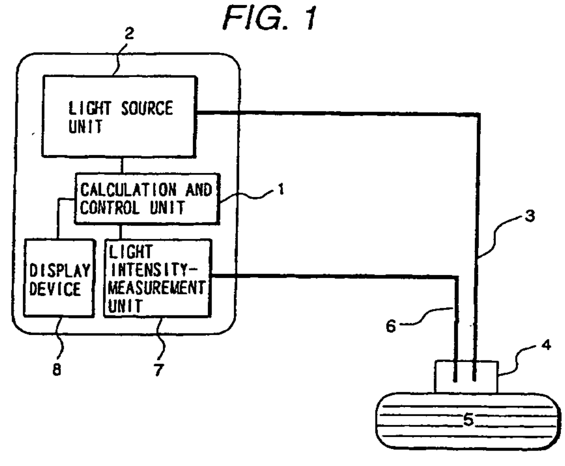
(54) METHOD FOR MEASURING WATER CONTENT, DEVICE FOR MEASURING WATER CONTENT, AND METHOD FOR PRODUCING ELECTRONIC DEVICE

(57) A measurement method and a compact measurement apparatus, which are capable of simply measuring the water content of an object member, with a high degree of accuracy, is characterized in performing the processes of: irradiating the surface of the objective member to be measured, with at least two kinds of monochromatic light beams of different wave length values, one of the wave length values being less than 1350 nm, the light beams being led by a light-guiding device for light-irradiation to the surface of the objective member; measuring the intensity of reflected light in each light beams, which is reflecting from the surface of the objective member, by leading the reflected light to a light intensity-measurement unit, with a light-guiding device for light-receive; obtaining the reflective absorbance (A_λ) of each light beam; calculating a reflective-absorbance differences (ΔA_λ) between, or a reflective-absorbance ratios (A_λ') of, the respective light beams, respectively; and estimating the water content of the measured object member by using the relationship between water content, and reflective-absorbance differences or reflective-absorbance ratios, the relationship being memorized in a memory device in advance.

FIG. 1



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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to a water content-measurement method and a water content-measurement apparatus which measure the water content of an object member to be measured, such as a paper, a film, etc., using light, and to an electrical component-fabrication method using the measurement method or the measurement apparatus.

BACKGROUND OF THE INVENTION

[0002] Concerning a method of measuring the water content of an object member to be measured, a two-color infrared water content-measurement device using absorbed light of 1.94 μ mwave length, and reference light of 1.7 or 1.8μm wave length, and obtaining the water content based on the ratio of two absorption degree signals of the absorbed light and the reference light, is known. Further, for example, Japanese Patent Application Laid-Open Hei 5-164690 discloses a three-color water content-measurement device, which does not receive an effect of a type of an object member to be measured, and an effect of humidity in air, by using absorption light of 1.96 and 2.0 μm wave lengths, and reference light of 1.9 and 2.1μm wave lengths. Also, for example, Japanese Patent Application Laid-Open Sho 60-93334 discloses a water content-measurement method suitable for measurement of high water content, which uses measurement light of 1.76 - 1.87 μm wave length, and reference light of 1.7μm wave length.

DISCLOSURE OF THE INVENTION

[0003] However, in the above conventional water content-measurement method and apparatus, since an output measurement signal indicating water content deviates due to even a small difference between wave length valuesl.7 and 1.8μm, the high measurement accuracy cannot be realized. Further, the size of the measurement apparatus becomes large because of obtaining monochromatic light from continuous spectrum light via a spectrograph or a filter.

[0004] Moreover, in the fabrication of electrical components such as transformers, motors, etc., since an insulating paper covering a coil conductor absorbs moisture during insulation paper-covering work or electrical component-assembling work, a dry process is performed after the assembling work is finished. However, since there has not been a portable water content-measurement device, and this causes the problem of that it is difficult to heuristically dry an insulation paper, etc., in just proportions, that is; needless time is consumed by overabundant dry-processing, or the insulation performance of the insulating papers is deteriorated by the shortage in drying the insulating papers due to improperly shortened dry-processing.

[0005] An objective of the present invention is to provide a water content-measurement method and a water content-measurement apparatus which is capable of measuring the water content of an object member to be measured, with a high degree of accuracy.

[0006] Another objective of the present invention is to provide a water content-measurement method which can downsize a water content-measurement apparatus, and a water content-measurement apparatus which can be compactly composed.

[0007] Further, another objective of the present invention is to provide an electrical component-fabrication method which is capable of efficiently fabricating an electrical component having excellent insulation characteristics.

[0008] From results of examining the relationship between water content and reflectance spectroscopic characteristics of an object member to be measured, it has been found that the water content of an object member to be measured can be calculated from the change in a reflective-absorbance difference between, or a reflective-absorbance ratio of, light beams of two specific wave length values.

[0009] The present invention provides a water content-measurement method in which the surface of an objective member to be measured is irradiated with a light beam of wave length at which reflective absorbance is largely affected by water content, and a light beam of other wave length at which reflective absorbance is hardly affected by water content, and the reflective absorbance of each light beam is obtained by measuring the intensity of reflected light in each light beam, said method comprises the steps of: irradiating the surface of the objective member to be measured, with at least two kinds of monochromatic light beams of different wave length values, one of the wave length values being less than 1350 nm, the light beams being led to the surface of the objective member by a light-guiding device for light-irradiation; measuring the intensity of reflected light in each light beams, which is reflecting from the surface of the objective member, by leading the reflected light to a light intensity-measurement unit, with a light-guiding device for light-receive; obtaining the reflective absorbance (A_λ) of each light beam, using the equation (1); calculating a reflective-absorbance differences (ΔA_λ) between, or a reflective-absorbance ratios (A_λ') of, the respective light beams, using the equation (2) or (3), respectively; and estimating the water content of the measured object member by using the calculated reflective-absorbance difference (ΔA_λ) or the calculated reflective-absorbance ratio (A_λ'), and the relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), the relationship being memorized in a memory device in advance.

Here,

$$A_\lambda = -\log (I_\lambda / I_{0,\lambda}) \quad (1),$$

$$\Delta A_\lambda = A_{\lambda 1} - A_{\lambda 2} \ (\lambda 1 > \lambda 2) \quad (2),$$

and

$$A_\lambda' = A_{\lambda 1} / A_{\lambda 2} \ (\lambda 1 > \lambda 2) \quad (3),$$

where I: the intensity of light reflecting from the surface of a standard white board, I_0: the intensity of the light reflecting from the surface of the measured object member, and λ_2: a wave length value less than 1350 nm.

[0010] Further, the present invention provides a water content-measurement apparatus for measuring water content by irradiating the surface of an objective member to be measured, with a light beam of wave length at which reflective absorbance is largely affected by water content, and a light beam of other wave length at which reflective absorbance is hardly affected by water content, and obtaining the reflective absorbance of each light beam based on a measured intensity value of reflected light in each light beam, said apparatus comprises: a light source for emitting at least two kinds of monochromatic light beams of different wave lengths, one of the wave length values being less than 1350 nm; a light-guiding device for light-irradiation, for leading the light beams emitted from the light source to the surface of the objective member; a light-guiding device for light-receive, for leading reflected light in each light beams, which is reflecting from the surface of the objective member; a light intensity-measurement unit for measuring the intensity of light radiated from the light-guiding device for light-receive; and a calculation and control unit which obtains the reflective absorbance (A_λ) of each light beam, calculates a reflective-absorbance difference (ΔA_λ) between, or a reflective-absorbance ratio (A_λ') of, the respective light beams, and estimates the water content of the measured object member by using the calculated reflective-absorbance difference (ΔA_λ) or the calculated reflective-absorbance ratio (A_λ'), and the relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), the relationship being memorized in a memory device in advance.

[0011] Furthermore, the present invention provides an method of fabricating an electrical component in which a coil conductor covered with an insulating paper is contained in a case, and insulation oil is poured into the case after the coil conductor covered with the insulating papers is dried, the method comprises the steps of: irradiating the surface of the insulating paper, with at least two kinds of monochromatic light beams of different wave length values, one of the wave length values being less than 1350 nm, said light beams being led to the surface of the insulating paper by a light-guiding device for light-irradiation; measuring the intensity of reflected light in each light beams, which is reflecting from the surface of the insulating paper, by leading the reflected light to a light intensity-measurement unit, with a light-guiding device for light-receive; obtaining the reflective absorbance (A_λ) of each light beam, using the equation (1); calculating a reflective-absorbance difference (ΔA_λ) between, or a reflective-absorbance ratio (A_λ') of, the respective light beams, using the equation (2) or (3), respectively; estimating the water content of the measured object member by using the calculated reflective-absorbance difference (ΔA_λ) or the calculated reflective-absorbance ratio (A_λ'), and the relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), the relationship being memorized in a memory device in advance; drying the coil conductor covered with the insulating paper until the water content of the coil conductor becomes less than a predetermined value; and pouring insulation oil into the case.

Here,

$$A_\lambda = -\log (I_\lambda / I_{0,\lambda}) \quad (1),$$

$$\Delta A_\lambda = A_{\lambda 1} - A_{\lambda 2} \ (\lambda 1 > \lambda 2) \quad (2),$$

and

$$A_\lambda' = All / A_{\lambda 2} \ (\lambda 1 > \lambda 2) \quad (3),$$

where I: the intensity of light reflecting from the surface of a standard white board, I_0: the intensity of light reflecting from the surface of the measured object member, and λ_2: a wave length value less than 1350 nm.

[0012] In addition, the present invention provides an method of fabricating an electrical component in which a stator core is wound by a coil conductor covered with an insulating paper, and a varnishing process is performed to the stator core and the coil conductor after the stator core wound by the coil conductor covered with the insulating papers is dried, said method includes the steps of: irradiating the surface of the insulating paper, with at least two kinds of monochromatic light beams of different wave lengths, one of the wave length being less than 1350 nm, the light beams being led to the surface of the insulating paper by a light-guiding device for light-irradiation; measuring the intensity of reflected light in each light beams, which is reflecting from the surface of the insulating paper, by leading the reflected light to a light intensity-measurement unit, with a light-guiding device for light-receive; obtaining the reflective absorbance (A_λ) of each light beam, using the equation (1); calculating a reflective-absorbance difference (ΔA_λ) be-

tween, or a reflective-absorbance ratio (A_λ') of, the respective light beams, using the equation (2) or (3), respectively; estimating the water content of the measured object member by using the calculated reflective-absorbance difference (ΔA_λ) or the calculated reflective-absorbance ratio (A_λ'), and the relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), the relationship being memorized in a memory device in advance; drying the coil conductor covered with the insulating paper until the water content of the coil conductor becomes less than a predetermined value; and performing a varnishing process for the stator core and the coil conductor.

Here,

$$A_\lambda = -\log (I_\lambda / I_{0,\lambda}) \quad (1),$$

$$\Delta A_\lambda = A_{\lambda 1} - A_{\lambda 2} \ (\lambda 1 > \lambda 2) \quad (2),$$

and

$$A_\lambda' = A_{\lambda 1} / A_{\lambda 2} \ (\lambda 1 > \lambda 2) \quad (3),$$

where I: the intensity of light reflecting from the surface of a standard white board, I_0: the intensity of light reflecting from the surface of the measured object member, and λ_2: wave length less than 1350 nm.

[0013] Further, concerning the wave lengths of the monochromatic light beams, it is preferable to set λ_1 in a range of 1400 - 2000 nm, and λ_2 in a range of 600 - 1350 nm.

[0014] Moreover, a semiconductor laser diode or a light emission diode, which emits light having a peak in a wave length range of 600 nm - 2000 nm, can be used for the monochromatic light source.

[0015] Also, it is preferable to use a glass fiber for the light-guiding device for light-irradiation, and the light-guiding device for light-receive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Fig. 1 is a schematic block diagram showing the composition of a water content-measurement apparatus of an embodiment according to the present invention.

[0017] Fig. 2 is a vertical cross section showing the internal structure of a probe in the water content-measurement apparatus shown in Fig. 1.

[0018] Fig. 3 is a flow chart of calculating water content, which is executed by the water content-measurement apparatus shown in Fig. 1.

[0019] Fig. 4 is a graph showing spectra of light reflecting from insulating papers of different water contents.

[0020] Fig. 5 is a characteristic curve showing the relationship between water content and reflective-absorbance differences.

[0021] Fig. 6 is a characteristic curve showing the relationship between water content and reflective-absorbance ratios.

[0022] Fig. 7 is a characteristic curve showing the relationship between water content and breakdown voltage.

[0023] Fig. 8 is a characteristic curve showing the relationship between water content and specific volume resistance.

[0024] Fig. 9 is a schematic diagram depicting a measurement system for performing a oil filled transformer-fabrication method according to the present invention by using the water content-measurement apparatus of the present invention.

[0025] Fig. 10 is a vertical cross. section of a probe in the water content-measurement apparatus shown in Fig. 9.

[0026] Fig. 11 is a side elevation of a stator fabricated by an electrical component-fabrication method according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0027] Results of examining the relationship between water content and reflectance spectroscopic characteristics of a measured object member shows that the water content of an object member to be measured can be calculated from the change in a reflective-absorbance difference between, or a reflective-absorbance ratio of, light beams of two specific wave lengths.

[0028] Water content is defined as a ratio of the weight of water included in an object member to the total weight of the object member. That is, by using each measured weight, this water content is obtained from the equation: (the total weight of an object member - the weight of water included in the object member) / the total weight of an object member.

[0029] That is, the water content of an object member to be measured can be accurately obtained by the following method comprising the steps of: irradiating the surface of the objective member to be measured, with at least two kinds of monochromatic light beams of different wave lengths, one of the wave length being less than 1350 nm, the light beams being led to the surface of the objective member by a light-guiding device for light-irradiation; measuring the intensity of light in each light beams, which is reflecting from the surface of the objective member, by leading the reflected light to a light intensity-measurement unit, with a light-guiding device for light-receive; obtaining the reflective absorbance (A_λ) of each light beam, using the equation (1); calculating a reflective-absorbance difference (ΔA_λ) between, or a reflective-absorbance ratio (A_λ') of, the respective light beams, using the equation (2) or (3), re-

spectively; and estimating the water content of the measured object member by using the calculated reflective-absorbance difference (ΔA_λ) or the calculated reflective-absorbance ratio (A_λ'), and the relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), the relationship being memorized in a memory device in advance.

Here,

$$A_\lambda = -\log (I_\lambda / I_{0,\lambda}) \quad (1),$$

$$\Delta A_\lambda = A_{\lambda 1} - A_{\lambda 2} \ (\lambda 1 > \lambda 2) \quad (2),$$

and

$$A_\lambda' = A_{\lambda 1} / A_{\lambda 2} \ (\lambda 1 > \lambda 2) \quad (3),$$

where I: the intensity of light reflecting from the surface of a standard white board, I_0: the intensity of light reflecting from the surface of the measured object member, and λ_2: a wave length value less than 1350 nm.

[0030] Further, as the wave length values of the respective monochromatic light beams used in the present invention, it is preferable to use light of 1400 - 2000 nm wave length in the near infrared region, whose absorbance changes depending on effects of water content, and light of less than 1350 nm wave length, preferably light of 600 - 1350 nm wave length in a visual and near infrared region, whose absorbance is scarcely affected by water content.

[0031] The reflective-absorbance spectrum which reflects variation in the water content of an object member to be measured, changes according to the variation of the water content (A < B < C) as shown in Fig.4 if a craft paper is used for an insulating paper. In the range of less than 1350 nm wave length, the reflective absorbance barely changes. However, the height of the peak near 1950 nm wave length in the reflective-absorbance spectrum largely changes as the water content increases, and the reflective absorbance increases in the wide range of 1400 - 2000 nm wave length in the reflective-absorbance spectrum due to the increase of the water content, which in turn makes it possible to accurately detect the water content.

[0032] Moreover, as the monochromatic light source, a semiconductor laser diode (LD) or a light-emission diode (LED), which emits light having a peak in a wave length range of 600 - 2000 nm, is suitable because these diodes can be easily obtained, and have a long life time, a stable performance, and a compact size. Specifically, an LD or an LED, which emits light having a peak at 660, 650, 660, 670, 695, 700, 770, 785, 820, 830, 870, 880, 940, 950, 1310, 1550 nm, is suitable for the monochromatic light sources.

[0033] An object member which is measured by the water content-measurement method and the water content-measurement apparatus according to the present invention, is mainly a paper made of vegetable fiber, such as a craft paper, a sulfite paper, a semi-chemical pulp paper, a chemiground pulp paper, a refiner groundwood pulp paper, etc.; a cellulose derivative paper such as a pressboard paper, a cyano-ethyled paper, an acetyled paper, etc.; a chemical compound added paper such as an amine paper, a morpholine paper, an activated alumina paper, etc.; a synthetic fiber mixed paper including hemp, ramie, mulberry fibers, etc.; a sheet or a film made of fiber such as cotton, sheep wool, rayon, etc; a synthetic-fiber sheet or film, made of polyamide, polyamide-imide, polyester, polyurethane, polyvinyle, polyacrylate, polyethylene, polyethylene-naphthalate, polyimide, polycarbonate, polyether-imide, polyethyleneterephthalate, polypropylene, acetate, polystylene, etc. Further, the water content-measurement method and the water content-measurement apparatus according to the present invention, are useful for measuring the water content of the surface of a molded article made of epoxy, urethane, polystylene, etc, an article of food, a drug medicine, a cosmetic, etc.

[0034] Fig. 1 is a schematic block diagram showing the composition of a water content-measurement apparatus of an embodiment according to the present invention. Fig. 2 is a vertical cross sectional view showing the internal structure of a probe used in the above water content-measurement apparatus. Further, Fig. 3 is a flow chart of calculating the water content of an object to be measured.

[0035] In Fig. 1 and Fig. 2, a calculation and control unit 1 includes a microprocessor in which a memory for storing measured data and a read-on memory are situated, and performs control of switching the wave length of a light beam emitted from a light source, calculation of water content, and control of display operations.

[0036] A light source unit 2 includes light sources for emitting two monochromatic light beams. For example, an LD for emitting light of λ_1 (1550 nm) wave length, and an LED for emitting light of λ_2 (950 nm) wave length, can be used for the two light sources, respectively.

[0037] A light-guiding device for light-irradiation leads a measurement light beam emitted from the light source unit 2 to a probe 4 so as to irradiate an object member to be measured, with the led light beam radiated from the probe 4. Further, a light-guiding device for light-receive leads light reflecting from the surface of the object member to a light intensity-measurement unit 7. Although plastic fiber, glass fiber, etc., can be used for the light-guiding device for light-irradiation and the light-guiding device for light-receive, glass fiber, whose attenuation factor at the wave length of the light used for the measurement is small, is suitable.

[0038] The light intensity-measurement unit 7 measures the intensity of light reflecting from the surface of

the object member.

[0039] A display device 8 is controlled by the calculation and control unit 1, and displays the measured water content.

[0040] The calculation and control unit 1 and the display device 8 can be composed using a notebook or laptop type personal computer.

[0041] In this water content-measurement apparatus, first, in order to obtain a reference level, the reflective absorbance of a measurement light beam of each wave length is measured by putting the probe 4 in touch with a standard white board. That is, a measurement light beam of λ_1 wave length, which has been generated in the light source unit 2, is led to the probe 4 through the light-guiding device for light-irradiation 3, and the standard white board is irradiated with the light beam led to the probe 4. Further, the light reflecting from the standard white board is led to the light intensity-measurement unit 7 through the light-guiding device 6 for light-receive. The light intensity-measurement unit 7 detects the intensity ($I_{0,\lambda 1}$) of the reflected light of λ_1 wave length, and the calculation and control unit 1 memorizes the detected intensity ($I_{0,\lambda 1}$). Furthermore, in the same manner, the intensity ($I_{0,\lambda 2}$) of the reflected light of λ_2 wave length is detected, and this detected intensity is stored in the calculation and control unit 1.

[0042] Next, the intensity of light reflecting from the object member 5 is measured. The probe 4 is put in touch with the surface of the object member 5, and the intensity values ($I_{\lambda 1}$, $I_{\lambda 2}$) of the reflected light of the respective wave lengths are detected in the same manner as in the detection of the reference intensify values of the reflected light of the respective wave lengths, which are obtained by using the standard white board, and th se values are memorized in the calculation and control unit 1. Further, the reflective absorbance of the light beam of each wave length is calculated and memorized.

[0043] The calculation and control unit 1 calculates the water content of the object member based on the relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), which is stored in advance. Further, the result of the calculation is displayed on the display device 8. Here, it is possible to store two groups of relational data expressing, that is: the relationship between water content and reflective-absorbance differences (ΔA_λ) and the relationship between water content and reflective-absorbance ratios (A_λ'), and selectively select one of the two groups, corresponding to the type of an object member. On the other hand, it is also possible to selectively store one of the two groups in advance, corresponding to the type of an object member.

[0044] The water content-measurement apparatus of this embodiment is composed so that an LD for emitting monochromatic light of λ_1 wave length and an LED for emitting monochromatic light of λ_2 wave length are provided in the light source unit 2; each measurement monochromatic light beam of λ_1 or λ_2 wave length, which is generated by the LD or the LED, is led to the probe 4 by the light-guiding devices 3 and 6; the reflected light in the light beam is led to the light intensity-measurement unit 7; and the intensity of the reflected light is converted to an electric signal by the light intensity-measurement unit 7. By the above composition, a portable type water content-measurement apparatus of 5kg weight can be realized.

Example 1 of measurement:

[0045] The water content of a craft paper was measured using the water content-measurement apparatus shown in Fig. 1 and Fig. 2. An LD emitting monochromatic light of λ_1 (= 1550 nm) wave length and an LED emitting monochromatic light of λ_2 (= 950 nm) wave length, were used in the light source unit 2.

[0046] First, after the craft paper of 0.25 mm thickness was dried at 120°C for 48 hours, the weight of the craft paper was measured, and the craft paper was left at room temperature. Then, the weight of the craft paper was measured again. The water content of the craft paper which had been left at room temperature, was calculated to be 3.6% from the weight change of the paper.

[0047] Next, the water content of the craft paper which had been left at room temperature, was measured using the water content-measurement apparatus shown in Fig. 1 and Fig. 2, in which monochromatic light of λ_1 (= 1550 nm) wave length, emitted by an LD, and monochromatic light of λ_2 (= 950 nm) wave length, emitted by an LED, were used. The water content of the craft paper was measured to be 3.7% by the method of measuring water content based on a reflective-absorbance difference, which is indicated in embodiment 1, and the 3.7% water content was displayed on the display device 8. The water content calculated from the weight change was 3.6%, and the high measurement accuracy was obtained.

Example 2 of measurement:

[0048] The water content of a pressboard paper was measured using the water content-measurement apparatus shown in Fig. 1 and Fig. 2. Here, an LD emitting monochromatic light of λ_1 (= 1550 nm) wave length and an LD emitting monochromatic light of λ_2 (= 830 nm) wave length, were used in the light source unit 2. Further, for each of the monochromatic light of 1550 nm wave length and the monochromatic light of 830 nm wave length, the relationship between water content and reflective-absorbance ratios had been input to the calculation and control unit 1 in advance.

[0049] First, after the pressboard paper of 0.8 mm thickness was dried at 120°C for 48 hours, the weight of the craft paper was measured, and the pressboard paper was left in a constant humidity bath. Then, the weight of the craft paper was measured again. The water content of the craft paper which had been left at room

temperature, was calculated to be 13.6% from the weight change of the paper.

[0050] Next, the water content of the pressboard paper which had been left at room temperature, was measured using the water content-measurement apparatus shown in Fig. 1 and Fig. 2., in which monochromatic light of λ_1 (=1550 nm) wave length, emitted by an LD, and monochromatic light of λ_2 (= 950 nm) wave length, emitted by an LD, were used. The water content of the craft paper was measured to be 13.5% by the method according to the present invention, and the 13.5% water content was displayed on the display device 8. Thus, the result indicates that the high measurement accuracy was obtained.

Example 3 of measurement:

[0051] The water content of an amine paper was measured using the water content-measurement apparatus shown in Fig. 1 and Fig. 2. Here, an LD emitting monochromatic light of λ_1 (= 1550 nm) wave length and an LD emitting monochromatic light of λ_2 (= 1310 nm) wave length, were used in the light source unit 2. Further, for each of the monochromatic light of 1550 nm wave length and the monochromatic light of 1310 nm wave length, the relationship between water content and reflective-absorbance ratios had been stored in the calculation and control unit 1 in advance.

[0052] First, after the amine paper of 0.25 mm thickness was dried at 120°C for 48 hours, the weight of the amine paper was measured, and the amine paper was left at room temperature. Then, the weight of the amine paper was measured again. The water content of the amine paper which had been left at room temperature, was calculated to be 5.5% from the weight change of the paper.

[0053] Next, the water content of the amine paper which had been left at room temperature was measured using the water content-measurement apparatus shown in Fig. 1 and Fig. 2., in which monochromatic light of λ_1 (= 1550 nm) wave length, emitted by an LD, and monochromatic light of λ_2 (= 1310 nm) wave length, emitted by an LD, were used.

[0054] Further, the water content of the amine paper was measured to be 5.5% by the method of measuring water content based on a reflective-absorbance difference, and the 5.5% water content was displayed on the display device 8. Thus, this indicates that the high measurement accuracy was obtained.

Example 4 of measurement:

[0055] The water content of an acetate fiber film was measured using the water content-measurement apparatus shown in Fig. 1 and Fig. 2. Here, an LD emitting monochromatic light of λ_1 (= 1550 nm) wave length and an LD emitting monochromatic light of λ_2 (= 635 nm) wave length, were used in the light source unit 2. Further, for each of the monochromatic light of 1550 nm wave length and the monochromatic light of 635 nm wave length, the relationship between water content and reflective-absorbance ratios had been stored in the calculation and control unit 1 in advance.

[0056] First, after the acetate fiber sheet of 0.5 mm thickness was dried at 120°C for 48 hours, the weight of the acetate sheet was measured, and the acetate fiber sheet was left at room temperature. Then, the weight of the acetate fiber sheet was measured again. The water content of the craft paper which had been left at room temperature, was calculated to be 6.4% from the weight change of the sheet.

[0057] Next, the water content of the acetate fiber sheet which had been left at room temperature was measured using monochromatic light of λ_1 (= 1550 nm) wave length, emitted by an LD, and monochromatic light of λ_2 (= 635 nm) wave length, emitted by an LD. The measured water content of the acetate fiber sheet was 6.5%, which indicates that the high measurement accuracy was obtained.

Example 5 of measurement:

[0058] The water content of a polyamide paper was measured using the water content-measurement apparatus shown in Fig. 1 and Fig. 2. Here, an LD emitting monochromatic light of λ_1 (= 1920 nm) wave length and an LD emitting monochromatic light of λ_2 (= 670 nm) wave length, which were obtained from white light via a spectrograph, were used. Further, for each of the monochromatic light of 1920 nm wave length and the monochromatic light of 700 nm wave length, the relationship between water content and reflective-absorbance differences, had been stored in the calculation and control unit 1 in advance.

[0059] First, the water content of the polyamide paper of 0.135 mm thickness was calculated to be 6.4% from the weight change of the polyamide paper in the same manner as in the example 1 of measurement.

[0060] Next, the water content of the polyamide paper was measured to be 6.6% by the method of measuring water content based on a reflective-absorbance difference, using monochromatic light of λ_1 (= 1920 nm) wave length and monochromatic light of λ_2 (= 700 nm) wave length, which were obtained from white light via a spectrograph.

Example 6 of measurement:

[0061] The water content of the polyamide film whose thickness is 0.025 mm, was measured to be 2.8% by the method of measuring water content based on a reflective-absorbance ratio, which was used in the example 1, by using monochromatic light of λ_1 (= 1400 nm) wave length and monochromatic light of λ_2 (= 600 nm) wave length (for each of the monochromatic light of 1400 nm wave length and the monochromatic light of

600 nm wave length, the relationship between water content and reflective-absorbance ratios had been stored in the calculation and control unit 1 in advance). On the other hand, the water content of the polyamide film was calculated to be 2.8% from the weight change of the paper.

Example 7 of measurement:

[0062] The water content of the sulfite paper whose thickness is 0.025 mm, was measured to be 7.8% by the method of measuring water content based on a reflective-absorbance ratio, which was used in the example 1, by using monochromatic light of λ_1 (= 2000 nm) wave length and monochromatic light of λ_2 (= 1350 nm) wave length (for each of the monochromatic light of 2000 nm wave length and the monochromatic light of 1350 nm wave length, the relationship between water content and reflective-absorbance ratios had been stored in the calculation and control unit 1 in advance). On the other hand, the water content of the sulfite paper was calculated to be 7.9% from the weight change of the paper.

[0063] Application example 1 to which the present inv ntion was applied:

[0064] The application example 1 is explained bellow. In this application example, the water content-measurement method according to the present invention is applied to a transformer-fabrication method achieving a high insulation performance of a transformer by maintaining a predetermined water-content value of an insulating paper used as an insulating member for covering a coil conductor in a high-pressure oil filled transformer while measuring the water content of the insulating paper in the transformer which has been assembled.

[0065] An insulating paper such as an oil-immersed pressboard paper has excellent electrical characteristics, and is indispensable for an insulating member in electrical equipment in which high voltage is used. However, cellulose fibers which are a main component of a paper is highly hygroscopic, and if the paper absorbs moisture, it loses the excellent electrical characteristics. Consequently, it loses the property of an insulating m mber. Therefore, managing the water content of an insulating paper is greatly important.

[0066] As shown in Fig. 7 and Fig. 8, the breakdown voltage and the specific volume resistance of an insulating paper such as a pressboard paper, decrease as the water content increases, and this may cause electric breakdown. Therefore, it is necessary to decrease the water content of the insulating paper by a hot-air drying method or a vacuum drying method.

[0067] Fig. 9 and Fig. 10 are diagrams for depicting a measurement system which measured the water content of a pressboard used for insulating a coil of an oil filled transformer of 50 MVA, by using the water content-measurement apparatus shown in Fig. 1 and Fig. 2.

[0068] The water content-measurement apparatus 10 fed a measurement light beam emitted from the respective light sources 2a (LD light source emitting light of 1550 nm wave length (λ_1)) and 2b (LD light source emitting light of 830 nm wave length (λ_2)), to the light-guiding device 3 for light-irradiation via an optical coupler 9. The probe 4 including a total reflection prism 4a and a stray light-shielding ring 4b, irradiated the object member to be measured (the standard white board 11 or the insulating paper) with the measurement light beam radiated from the light-guiding device 3 for light-irradiation. Further, the probe 4 led the light reflecting from the object member into the light-guiding device 6 for light-receive.

[0069] In the oil-filled transformer 12, a coil 14, covered by an insulation pressboard paper and wound on an iron core 13, was put into a case 15.

[0070] At the case 15 of the oil-filled transformer 12, three holes were formed, that is: a measurement hole 15a through which the light-guiding device 3 for light-irradiation and the light-guiding device 6 for light-receive were hermetically penetrated in order to put the probe 4 in touch with the surface (the pressboard) of the coil 14; a hot air-introducing hole 15b for introducing hot air ejected from a heating air blower 16 to the bottom space in the case 15; and an air-exhaust hole 15c for exhausting the hot air which had dried the inside of the case 15, and had absorbed moisture.

[0071] The top portion of an air-suction pipe 17a connected to a vacuum-drying air-exhaust pump 17 was constructed so that the pump 17 was hermetically connected to the hot air-introducing hole 15c.

[0072] Further, a tight seal plug 18 for sealing the air-exhaustion hole 15c of the case 15 was prepared.

[0073] Also, the oil-filled transformer 12 was assembled so that the iron core 13, on which the coil 14 was wound, was contained in the case 15.

[0074] Under the above conditions, in order to obtain a reference level, the intensity of reflected light in each of the light beams emitted from each of the light sources 2a and 2b, which is reflecting from a standard white board, was measured by putting the probe 4 of the water content-measurement apparatus 10 in touch with the standard white board 11. First, the LD light source 2a emitting a light beam whose wave length λ_1 was 1550 nm, was turned on, and the intensity ($I_{0,\lambda 1}$) of the light reflecting from the standard white board 11 was measured. This measured intensity of the reflected light was stored in the calculation and control unit 1. Further, the LD light source 2b emitting a light beam whose wave length λ_2 was 830 nm, was turned on, and the intensity ($I_{0,\lambda 2}$) of the light reflecting from the standard white board 11 was measured. This measured intensity was also stored in the calculation and control unit 1.

[0075] Next, the light-guiding devices 3 and 6 of the water content-measurement apparatus 10 were hermetically penetrated through the measurement hole 15a of the case 15 of the transformer 12, and the probe 4 was put in touch with the surface of the coil 14. Then, the water content of the surface portion (pressboard pa-

per) of the coil was measured. In the same manner as in the measurement for the standard white board 11, the intensity values ($I_{\lambda 1}$, $I_{\lambda 2}$) of two kinds of light reflecting from the surface portion of the coil 14, whose wave length values were λ_1 and λ_2, respectively, were measured, and these intensity values were stored in the calculation and control unit 1. Further, the reflective absorbance values ($A_{\lambda 1}$, $A_{\lambda 2}$) of the two kinds of the light reflecting from the surface portion of the coil 14, having the respective two wave length values, were calculated. Furthermore, a reflective-absorbance difference (ΔA_{λ}) between the two reflective absorbance values ($A_{\lambda 1}$, $A_{\lambda 2}$) was calculated and stored. Then, the water content was calculated using the relationship between water content and reflective-absorbance differences (ΔA_{λ}) such as that shown in Fig. 5. In this example, the calculation result of the water content indicated 8.2%. Moreover, the dry conditions corresponding the obtained water content, such as drying time, were obtained, and they were displayed on the display device 8.

[0076] In drying operations, while the dry conditions shown on the display device 8 was referred to, an air-blasting pipe 16a connected to the heating air blower 16 was put through the hot air-introducing hole 15b, and hot air which had been heated to 110°C was fed to the bottom space in the case 15, corresponding with the m asured water content. The hot air which was fed to the bottom portion of the case 15, dried the inside of the case 15 while absorbing moisture, and was expelled from the air-exhaust hole 15c to the outside. After the hot-air drying operation was finished, the air-blasting pipe 16a was withdrawn through the hot air-introducing hole 15b, and the air-suction pipe 17a connected to the vacuum-drying air-exhaust pump 17 was connected to th hot air-introducing hole 15b, and the air-exhaust hole 15c was sealed with the tight seal plug 18. Then, the inside of the case 15 was vacuum-dried by operating the vacuum-drying air-exhaust pump 17. After the above vacuum-drying was finished, the surface portion of the coil 14 was measured, and the result of the measurement indicated 0.5%.

[0077] Further, the light-guiding devices 3 and 6 of the water content-measurement apparatus 10 was withdrawn, and the probe 4 was taken out. Furthermore, the air-suction pipe 17a of the vacuum-drying air-exhaust pump 17 was withdrawn, and the drying operation was finished, and the case 15 was filled with insulation oil. Thus, the oil-filled transformer having excellent insulation-characteristics could be fabricated.

[0078] Application example 2 to which the present invention was applied:

[0079] Insulation covering processes of a stator of a motor are the same as the above-described processes. A stator of a motor is fabricated by winding a stator coil covered with an insulating paper on a stator core, and the insulation process of impregnating the stator coil and the stator core with insulating varnish is performed after drying them. It is desirable that the water content of the insulating paper is to be maintained at a predetermined value.

[0080] Fig. 11 schematically shows the composition of a stator 21 of a motor, which is fabricated by winding a stator coil 19 covered with a polyamide insulating paper on a stator core 20.

[0081] By using a water content-measurement apparatus (the showing of it is omitted) similar to the measurement apparatus shown in Fig. 11, which was used for the application example 1, in order to obtain a reference level, the intensity of light reflecting from a standard white board, in a light beam emitted from each light source, was first measured by putting a probe of the water content-measurement apparatus in touch with a standard white board 11. Next, the probe 4 was put in touch with the surface (polyamide paper) of the stator coil 19, and the intensity values ($I_{\lambda 1}$, $I_{\lambda 2}$) of two kinds of light reflecting from the surface of the stator coil, whose wave length values were λ_1 and λ_2, respectively, were measured, and these intensity values were stored in the calculation and control unit. Further, the reflective absorbance values ($A_{\lambda 1}$, $A_{\lambda 2}$) of the two kinds of the light reflecting from the surface of the stator coil 19, having the respective two wave length values, were calculated. Furthermore, the reflective-absorbance ratio (A_{λ} ') between the two reflective absorbance values was calculated and stored. Then, the water content was calculated using the relationship between water content and reflective-absorbance ratios (A_{λ}') such as that shown in Fig. 6. In this example, the calculation result of the water content indicated 7.2%. Moreover, the dry conditions corresponding the obtained water content, such as drying time, were obtained, and they were displayed on the display device.

[0082] In drying operations, while the dry conditions shown on the display device 8 was referred to, the stator 21 was put into an electric oven in which the temperature is kept at 130°C, and the stator 21 was dried. Then, the water content of the surface of the stator was measured to be 0.5%.

[0083] After the drying operations were finished, insulation processing was performed for the stator coil 19 by using insulation varnish, and the stator 21 having excellent insulation-characteristics could be fabricated.

[0084] By the above-described water content-measurement method and apparatus, since the water content of an object can be non-destructively and simply measured, it is possible to efficiently and reliably dry an insulating paper used in a transformer or motor to be in a proper dry state (water content), while measuring the water content of it. Further, by filling it with insulation oil, or performing an insulation process using insulation varnish, it is possible to fabricate a highly reliable transformer or a motor which has a high breakdown voltage and excellent insulation characteristics.

INDUSTRIAL APPLICABILITY OF THE INVENTION

[0085] In accordance with the present invention, the water content of an object member such as a paper, a film, etc., can be non-destructively, accurately, and simply measured.

[0086] Further, it is possible to provide a water content-measurement apparatus which can be portably used.

[0087] Furthermore, by using such a water content-measurement apparatus, an electrical component having excellent insulation characteristics can be efficiently fabricated.

Claims

1. A water content-measurement method in which a surface of an objective member to be measured is irradiated with a light beam of wave length at which reflective absorbance is largely affected by water content and a light beam of other wave length at which reflective absorbance is hardly affected by water content, and reflective absorbance of each light beam is obtained by measuring intensity of reflected light in each light beam, which is reflecting from said surface of said object member, said method comprising the steps of:

   irradiating said surface of said objective member with at least two kinds of monochromatic light beams of different wave length values, one of said wave length values being less than 1350 nm, said light beams being led to said surface of said objective member by a light-guiding device for light-irradiation;
   measuring intensity of reflected light in each light beams, which is reflecting from said surface of said objective member, by leading said reflected light to a light intensity-measurement unit, using a light-guiding device for light-receive;
   obtaining reflective absorbance (A_λ) of each light beam, using equation (1);
   calculating a reflective-absorbance difference (ΔA_λ) between, or a reflective-absorbance ratio (A_λ') of, said respective light beams, using equation (2) or (3), respectively;
   and estimating water content of said measured object member by using said calculated reflective-absorbance difference (ΔA_λ) or said calculated reflective-absorbance ratio (A_λ'), and relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), said relationship being memorized in a memory device in advance;
   wherein,

$$A_\lambda = -\log (I_\lambda / I_{0,\lambda}) \quad (1),$$

$$\Delta A_\lambda = A_{\lambda 1} - A_{\lambda 2} \text{ (here, } \lambda 1 > \lambda 2) \quad (2),$$

and

$$A_\lambda' = A_{\lambda 1} / A_{\lambda 2} \text{ (here, } \lambda 1 > \lambda 2) \quad (3),$$

   where I: intensity of light reflecting from a surface of a standard white board, I_0: said intensity of said light reflecting from said surface of said object member to be measured, and λ_2: a wave length value less than 1350 nm.

2. A water content-measurement method according to claim 1, wherein said wave length value λ_1 of one of said two kinds of said monochromatic light beams is in a range of 1400-2000 nm, and said wave length value $\lambda 2$ of another of said two kinds of said monochromatic light beams is in a range of 600 - 1350 nm,

3. A water content-measurement method according to claim 1, wherein one of a semiconductor laser diode and a light-emitting diode, which has a peak in a range of 600-2000 nm, is used as a light source of each monochromatic light beam.

4. A water content-measurement method according to any one of claims 1 to 3, wherein glass fibers are used for said light-guiding device for light-irradiation and said light-guiding device for light-receive.

5. a water content-measurement apparatus in which a surface of an objective member to be measured is irradiated with a light beam of wave length at which reflective absorbance is largely affected by water content, and a light beam of other wave length at which reflective absorbance is hardly affected by water content, and reflective absorbance of each light beam is obtained by measuring intensity of reflected light in each light beam, which is reflecting from said surface of said object member, said apparatus comprising:

   a light source for emitting at least two kinds of monochromatic light beams of different wave length values, one of said wave length values being less than 1350 nm;
   a light-guiding device for light-irradiation, for leading said light beams emitted from the light source to said surface of said objective member;
   a light-guiding device for light-receive, for lead-

ing reflected light in each light beams, which is reflecting from said surface of said objective member;
a light intensity-measurement unit for measuring intensity of light radiated from said light-guiding device for light-receive;
and a calculation and control unit which obtains reflective absorbance (A_λ) of each light beam, calculates a reflective-absorbance difference (ΔA_λ) between, or a reflective-absorbance ratio (A_λ') of, said respective light beams, and estimates water content of said measured object member by using said calculated reflective-absorbance difference (ΔA_λ) or said calculated reflective-absorbance ratio (A_λ'), and relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), said relationship being memorized in a memory device in advance.

6. A water content-measurement apparatus according to claim 5, wherein said wave length value $\lambda 1$ of one of said two kinds of said monochromatic light beams is in a range of 1400 - 2000 nm, and said wave length value $\lambda 2$ of another of said two kinds of said monochromatic light beams is in a range of 600 - 1350 nm,

7. A water content-measurement apparatus according to claim 5, wherein one of a semiconductor laser diode and a light-emitting diode, which has a peak in a range of 600-2000 nm, is used as a light source of each monochromatic light beam.

8. A water content-measurement method according to any one of claims 5 to 7, wherein glass fibers are used for said light-guiding device for light-irradiation and said light-guiding device for light-receive.

9. A method of fabricating an electrical component in which a coil conductor covered with an insulating paper is contained in a case, and insulation oil is poured into said case after said coil conductor covered with the insulating paper is dried, said method comprising the steps of:

irradiating a surface of said insulating paper, with at least two kinds of monochromatic light beams of different wave length values, one of said wave length values being less than 1350 nm, said light beams being led to said surface of said insulating paper by a light-guiding device for light-irradiation;
measuring intensity of reflected light in each light beams, which is reflecting from said surface of said insulating paper, by leading said reflected light to a light intensity-measurement unit, using a light-guiding device for light-receive;
obtaining reflective absorbance (A_λ) of each light beam, using equation (1);
calculating a reflective-absorbance difference (ΔA_λ) between, or a reflective-absorbance ratio (A_λ') of, said respective light beams, using equation (2) or (3), respectively;
estimating water content of said measured object member by using said calculated reflective-absorbance difference (ΔA_λ) or said calculated reflective-absorbance ratio (A_λ'), and relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), said relationship being memorized in a memory device in advance;
drying said coil conductor covered with said insulating paper until said water content of said coil conductor becomes less than a predetermined value; and
pouring insulation oil into the case;
wherein,

$$A_\lambda = -\log (I_\lambda / I_{0,\lambda}) \quad (1),$$

$$\Delta A_\lambda = A_{\lambda 1} - A_{\lambda 2} \text{ (here, } \lambda 1 > \lambda 2) \quad (2),$$

and

$$A_\lambda' = A_{\lambda 1} / A_{\lambda 2} \text{ (here, } \lambda 1 > \lambda 2) \quad (3),$$

where I: intensity of light reflecting from a surface of a standard white board, I_0: said intensity of said light reflecting from said surface of said measured object member, and λ_2: a wave length value less than 1350 nm.

10. A method of fabricating an electrical component in which a stator core is wound by a coil conductor covered with a insulating paper, and a varnishing process is performed for said stator core and said coil conductor after said stator core wound by said coil conductor covered with said insulating papers is dried, said method comprising the steps of:

irradiating a surface of said insulating paper, with at least two kinds of monochromatic light beams of different wave length values, one of said wave length values being less than 1350 nm, said light beams being led to said surface of said insulating paper by a light-guiding device for light-irradiation;
measuring intensity of reflected light in each light beams, which is reflecting from said surface of said insulating paper, by leading said

reflected light to a light intensity-measurement unit, with a light-guiding device for light-receive; obtaining reflective absorbance (A_λ) of each light beam, using equation (1);
calculating a reflective-absorbance difference (ΔA_λ) between, or a reflective-absorbance ratio (A_λ') of, the respective light beams, using equation (2) or (3), respectively;
estimating water content of said measured object member by using said calculated reflective-absorbance difference (ΔA_λ) or said calculated reflective-absorbance ratio (A_λ'), and relationship between water content, and reflective-absorbance differences (ΔA_λ) or reflective-absorbance ratios (A_λ'), said relationship being memorized in a memory device in advance;
drying said coil conductor covered with said insulating paper until said water content of said coil conductor becomes less than a predetermined value; and
performing a varnishing process for said stator core and said coil conductor;

wherein,

$$A_\lambda = -\log (I_\lambda / I_{0,\lambda}) \quad (1),$$

$$\Delta A_\lambda = A_{\lambda 1} - A_{\lambda 2} \text{ (here, } \lambda 1 > \lambda 2) \quad (2),$$

and

$$A_\lambda ' = A_{\lambda 1} / A_{\lambda 2} \text{ (here, } \lambda 1 > \lambda 2) \quad (3),$$

where I: intensity of light reflecting from a surface of a standard white board, I_0: said intensity of said light reflecting from said surface of said measured object member, and λ_2: a wave length value less than 1350 nm.

11. A method of fabricating an electrical component according to one of claim 9 and claim 10, wherein said wave length value λ1 of one of said two kinds of said monochromatic light beams is in a range of 1400 - 2000 nm, and said wave length value λ2 of another of said two kinds of said monochromatic light beams is in a range of 600 - 1350 nm,

12. A method of fabricating an electrical component according to one of claim 9 and claim 10, wherein one of a semiconductor laser diode and a light-emitting diode, which has a peak in a range of 600 - 2000 nm, is used as a light source of each monochromatic light beam.

13. A method of fabricating an electrical component according to any one of claims 9 to 12, wherein glass fibers are used for said light-guiding device for light-irradiation and said light-guiding device for light-receive.

FIG. 1

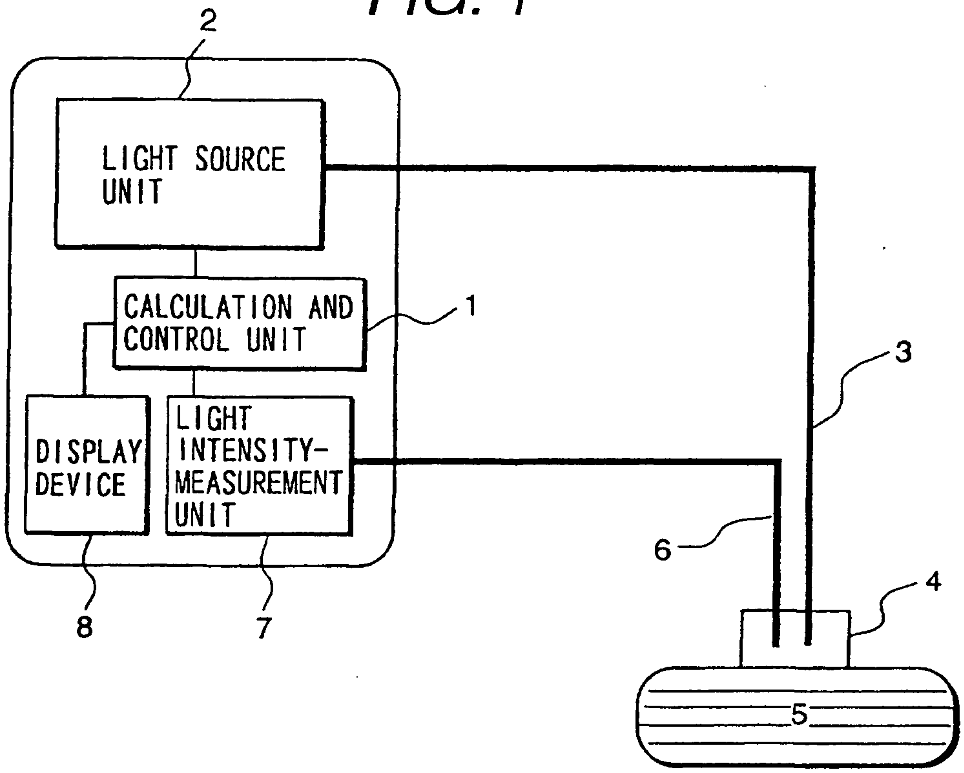

2
LIGHT SOURCE UNIT
CALCULATION AND CONTROL UNIT
1
3
DISPLAY DEVICE
LIGHT INTENSITY-MEASUREMENT UNIT
6
4
8
7
5

FIG. 2

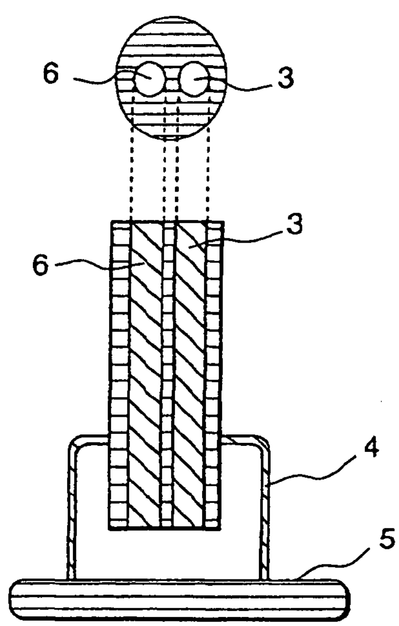

6
3
3
6
4
5

FIG. 3

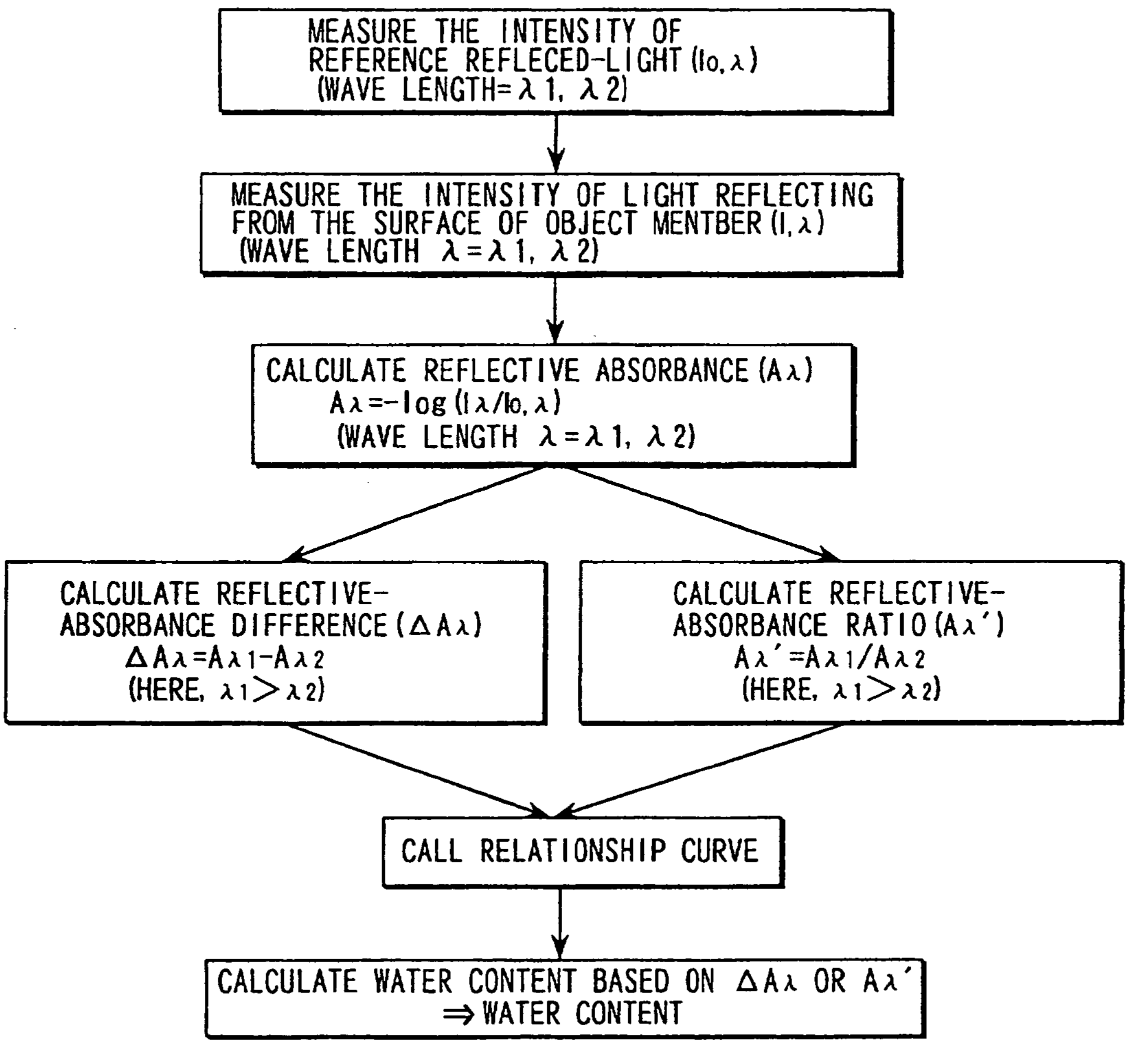

MEASURE THE INTENSITY OF
REFERENCE REFLECED-LIGHT (Io, λ)
(WAVE LENGTH=λ 1, λ 2)
MEASURE THE INTENSITY OF LIGHT REFLECTING
FROM THE SURFACE OF OBJECT MENTBER (I, λ)
(WAVE LENGTH λ=λ 1, λ 2)
CALCULATE REFLECTIVE ABSORBANCE (Aλ)
Aλ=-log (Iλ/Io, λ)
(WAVE LENGTH λ=λ 1, λ 2)
CALCULATE REFLECTIVE-
ABSORBANCE DIFFERENCE (ΔAλ)
ΔAλ=Aλ1-Aλ2
(HERE, λ1>λ2)
CALCULATE REFLECTIVE-
ABSORBANCE RATIO (Aλ′)
Aλ′=Aλ1/Aλ2
(HERE, λ1>λ2)
CALL RELATIONSHIP CURVE
CALCULATE WATER CONTENT BASED ON ΔAλ OR Aλ′
⇒WATER CONTENT

FIG. 4

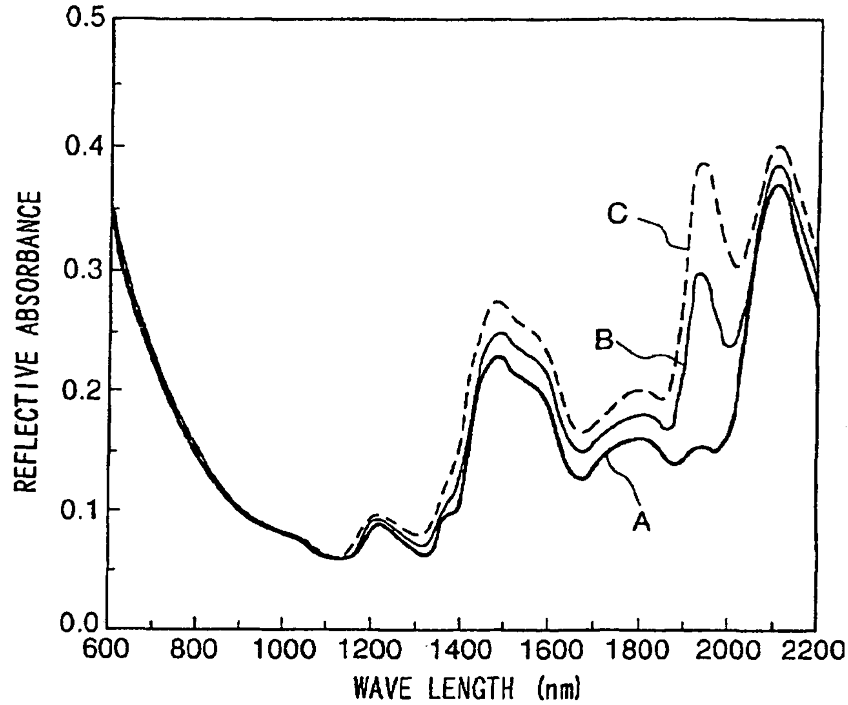

0.5
0.4
0.3
0.2
0.1
0.0
REFLECTIVE ABSORBANCE
C
B
A
600
800
1000
1200
1400
1600
1800
2000
2200
WAVE LENGTH (nm)

FIG. 5

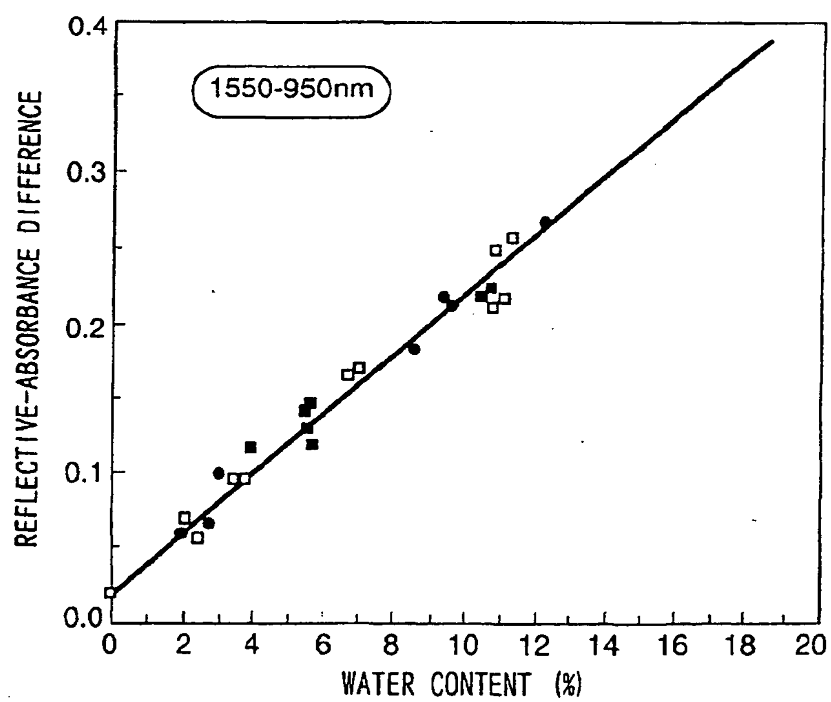

0.4
0.3
0.2
0.1
0.0
REFLECTIVE-ABSORBANCE DIFFERENCE
1550-950nm
0
2
4
6
8
10
12
14
16
18
20
WATER CONTENT (%)

FIG. 6

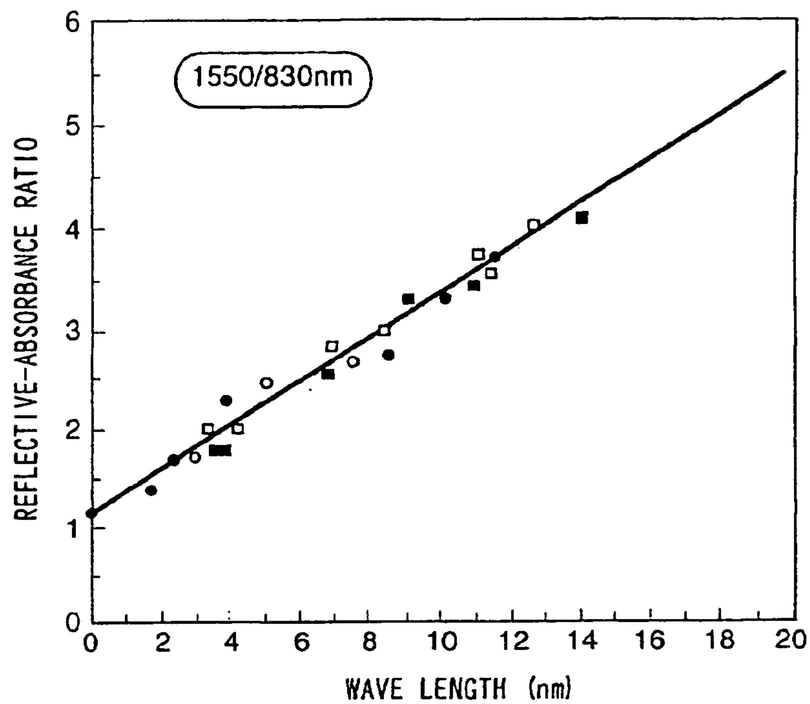

1550/830nm
REFLECTIVE-ABSORBANCE RATIO
WAVE LENGTH (nm)
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
16
18
20

FIG. 7

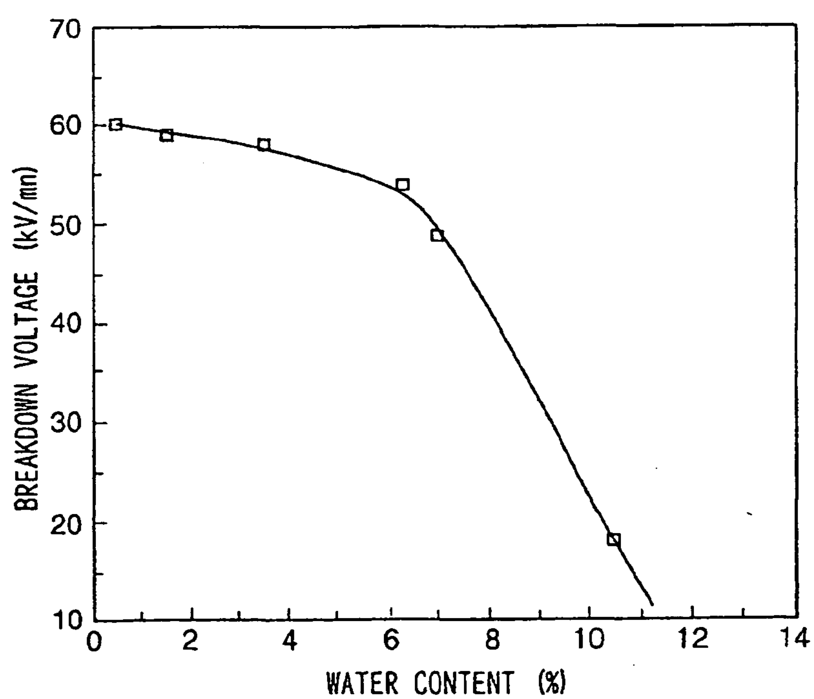

BREAKDOWN VOLTAGE (kV/mm)
WATER CONTENT (%)
10
20
30
40
50
60
70
0
2
4
6
8
10
12
14

FIG. 8

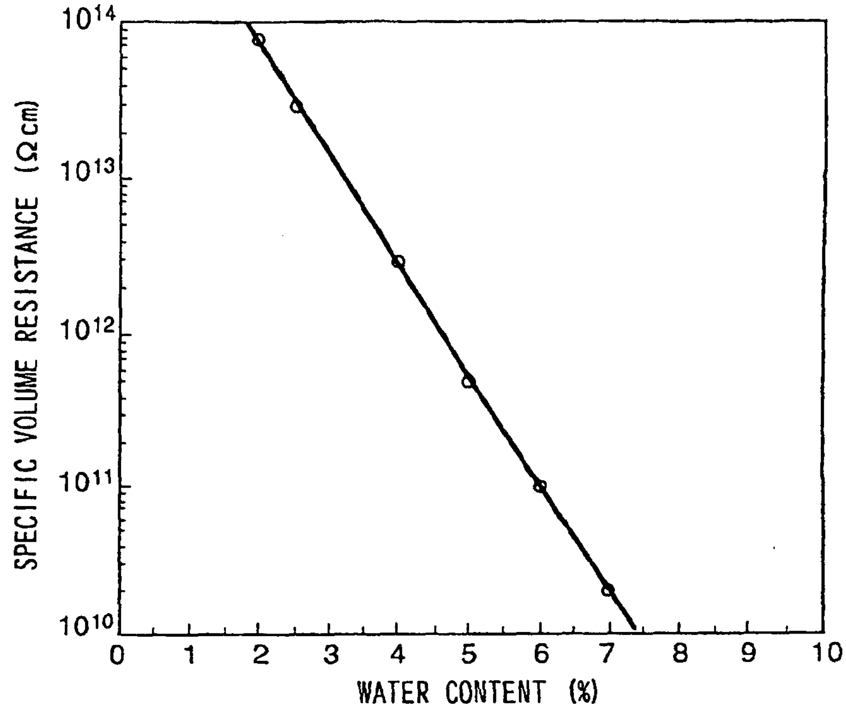

SPECIFIC VOLUME RESISTANCE (Ω cm)
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
0 1 2 3 4 5 6 7 8 9 10
WATER CONTENT (%)

FIG. 9

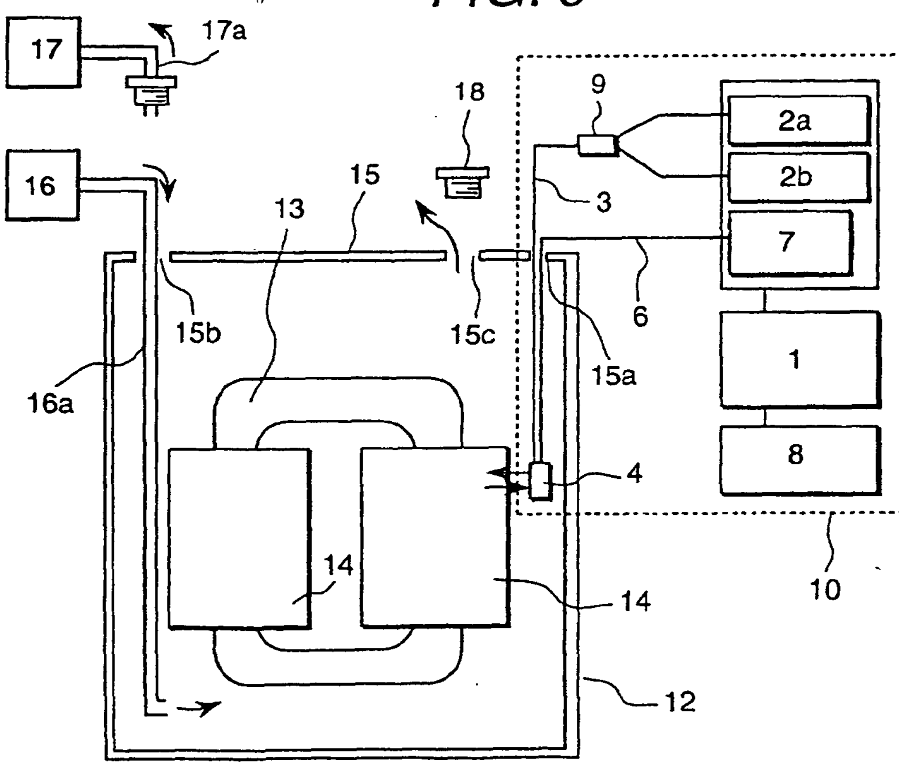

17
17a
18
9
2a
2b
16
15
13
3
7
15b
15c
6
15a
16a
1
8
4
14
14
10
12

FIG. 10

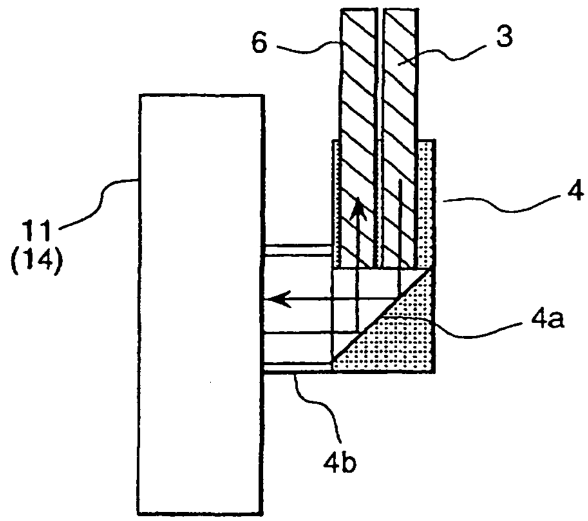
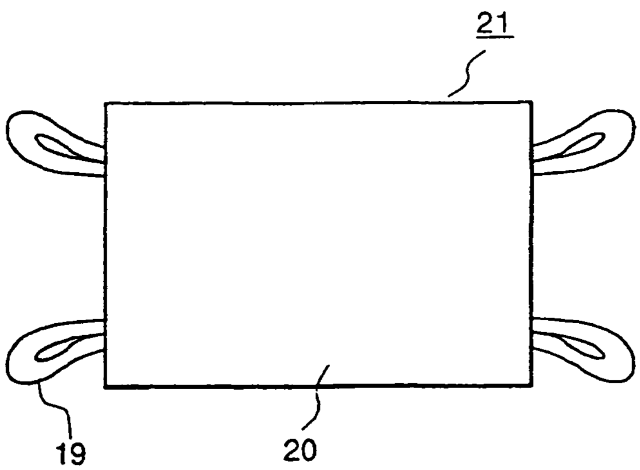


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP99/05954

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁷ G01N21/35

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl⁷ G01N21/00-21/01, 21/17-21/61,
H01F41/12, H02K15/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2000
Kokai Jitsuyo Shinan Koho	1971-2000	Jitsuyo Shinan Toroku Koho	1996-2000

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPI/L, JICST(JOIS)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 9-152400, A (Ricoh Company, Ltd.), 10 June, 1997 (10.06.97), 段落番号[0005]-[0009] (Family: none)	1-13
Y	JP, 48-42953, Y2 (Sanyo Kokusaku Parupe K.K., et al.), 12 December, 1973 (12.12.73), page 2, left column, lines 19-43; Figs. 1, 2 (Family: none)	1-13
Y	EP, 834730, A2 (HITACHI, LTD.), 08 April, 1998 (08.04.98), Full text; Fig. 1 & JP, 10-111241, A	1-13
Y	JP, 10-74628, A (Hitachi, Ltd.), 17 March, 1998 (17.03.98), Full text; Figs. 1 to 2 (Family: none)	1-13
Y	JP, 7-306137, A (Kokusai Denshin Denwa Co., Ltd.(KDD)), 21 November, 1995 (21.11.95), Par. No. [0003] (Family: none)	4,8,13

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, 5343045, A (ONTARIO HYDRO), 30 August, 1994 (30.08.94), Full text; Fig. 1 & EP, 628803, A & JP, 7-20045, A	9,11-13
Y	JP, 63-12118, A (Toshiba Corporation), 19 January, 1988 (19.01.88), page 1, lower left column, line 17 to lower right column, line 16; Figs. 1 to 2 (Family: none)	9,11-13
Y	JP, 1-129735, A (Toshiba Corporation), 23 May, 1989 (23.05.89), page 2, lower right column, line 11 to page 3, upper left column, line 4 (Family: none)	10-13

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